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# Analyses of response latency and hypothesis behavior for learning set performance obtained from the bluejay (*Cyanocitta cristata*) using two and three dimensional stimuli.

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Analyses of Response Latency and Hypothesis Behavior for  
Learning Set Performance Obtained from the Bluejay  
(Cyanocitta cristata) Using Two and  
Three Dimensional Stimuli

A Dissertation Presented

by

Maxwell W. Hunter III.

Submitted to the Graduate School of the  
University of Massachusetts in  
partial fulfillment of the requirements for the degree of

Doctorate of Philosophy

October, 1971

Major Subject: Psychology

Analyses of Response Latency and Hypothesis Behavior for  
Learning Set Performance Obtained from the Bluejay

(Cyanocitta cristata) Using Two and

Three Dimensional Stimuli (October, 1971)

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M.S., University of Massachusetts

Directed by: Dr. Alan C. Kamil

Two groups of subjects containing four bluejays each acquired learning set behavior, one group using three-dimensional stimuli and the other using two-dimensional stimuli. The subjects switched apparatuses following acquisition to allow assessment of transfer behavior. Analyses were performed on response latency data and for Hypothesis Behavior (Levine, 1959). Results suggested the superiority of the three-dimensional stimuli and accompanying procedure. The eight subjects were originally drawn from two nests and a difference between broods was evident throughout the data.

## ACKNOWLEDGEMENTS

I would like to thank the members of my dissertation committee for their many helpful suggestions. In particular, Dr. Alan Kamil performed the complex role of chief advisor with admirable grace. Dr. Arnold Well contributed an invaluable service by retrieving my early statistical analyses from the realm of the absurd.

My deepest admiration is reserved for the Northern Bluejay, particularly those individual birds who served in this research.

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-e.e. cummings

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For many years the learning set (LS) paradigm has been employed as a tool of comparative psychologists. In general terms it has been suggested that LS behavior is an indicator of behavioral plasticity in a species. This interpretation of LS performance has received substantial support from studies on nonhuman primates (see Miles, 1965, for review). Warren (1965) compares data for several species including: rhesus monkey, squirrel monkey, marmoset, cat, rat, and squirrel. Consistent with once popular notions of "animal intelligence", the rhesus monkey is clearly superior to the other species on this task, while the rat and squirrel perform at low levels of proficiency.

Unfortunately, it is not clear what behavioral potential is reflected in LS behavior. An earlier assumption that LS proficiency might correlate with a phylogenetic scale has been attacked by Hodos and Campbell (1970). As part of their criticism of the idea of a linear phylogenetic scale, these authors note that the LS literature does not contain data from several critical taxonomic groups including reptiles, monotremes, and prosimians. On the basis of several LS studies, Hodos (1969) concluded that LS performance is related to only one type of plasticity, and adds the obvious statement that failure of a species to demonstrate LS behavior does not mean that these animals lack potential for behavioral modification.

Other studies (Schusterman, 1964, and Warren, 1966) have obtained data to suggest that the acquisition of LS behavior may reflect different processes in different species. For example, Warren trained cats and rhesus monkeys on a reversal task using a single object pair. Both species were then switched to LS problems and tested for transfer. The monkeys showed virtually complete transfer and the cats demonstrated zero transfer. These data suggest that quantitative differences in one type of plasticity may be an unsatisfactory way to view species differences in LS behavior.

Against the background of these troublesome ambiguities in interpretation, we can consider the LS research with avian species. Zeigler (1961) obtained a relatively low level of performance from the pigeon. The two subjects showing the greatest learning set development reached 60% correct on Trials 2-8, when these trials were taken as a block. Unfortunately, Zeigler's presentation of data points averaged over blocks of trials, i.e., Trials 2-8, Trials 9-16, and Trials 17-24 causes a problem. It is relatively difficult to compare performance reported in this form with most LS studies where percentage correct on Trial 2 is the usual measure. In spite of this problem a few authors (Zeigler, 1961, and Warren, 1965) have implied that the pigeon's LS is only slightly inferior to several nonprimate mammals, e.g., cats and rats.

Kamil and Hunter have recently introduced certain avian species of the Corvidae Family to the learning set paradigm (Kamil and Hunter, 1970; Hunter and Kamil, 1971). In these experiments bluejays (Cyanocitta cristata) and mynas (Gracula religiosa) demonstrated asymptotic Trial 2 performance levels above 70% correct. The bluejays' Trial 2 level of 75% correct is not only clearly "superior" to several nonprimate mammals, it is actually comparable to some primate species (Warren, 1965).

A comparison of the results obtained by Zeigler for the pigeon and Kamil and Hunter for Corvids reveals several methodological differences between experiments. First, Zeigler employed two-dimensional stimuli projected onto response keys. These stimuli were photographed from the extensive population of randomly-paired objects maintained by the University of Wisconsin Primate Laboratory. In contrast to this procedure, Kamil and Hunter employed multidimensional stimulus objects. These differences in stimuli dictated a difference in the response-reward delivery sequence. Zeigler's pigeons pecked the keys and retrieved reward from a single food cup placed below the keys. The birds in the Kamil and Hunter studies were required to displace an object covering a foodwell containing reward. It should also be noted that Zeigler's apparatus was completely automated while Kamil and Hunter's was manually operated.

These rather extensive differences in methodology

raise some doubt in comparing the data. A major aim of this experiment was to provide data from Corvids in an apparatus comparable to Zeigler's. In order to accomplish this objective the subjects were divided into two groups and trained in two different LS situations. The first procedure employed two-dimensional stimuli, a single food cup, and was completely automated. The second used multi-dimensional objects and retained the usual features of a WGTA. Results obtained from these two procedures, especially the completely automated group, should allow a less ambiguous comparison between pigeons' and bluejays' LS behavior.

In addition to the interspecies comparison, this experiment was designed to provide valuable data from a single species tested in two situations. Meyer et al. (1965) reviewed several LS procedures and variables that have been employed in primate research, and concluded that no apparatus equals the manually operated WGTA (with three-dimensional stimuli) for the efficient acquisition of LS behavior. It is implied that certain other procedures, particularly the employment of two dimensional stimuli or noncontiguity, result in inefficient LS behavior below the animal's potential. It is not clear that these methodological variables will have similar effects in an avian species. In addition to the theoretical interest that attaches to this question, there is a practical matter involved. Potentially, it is much more convenient to



design and execute LS experiments with avian species in an automated apparatus. If it is shown from this research that bluejays acquire identical LS behavior in both situations, then future research could proceed at an accelerated rate.

Another purpose of this research was to examine certain theoretical notions of process in LS behavior. To be specific, Levine (1959) proposed a descriptive mathematical model for LS in primates. Several descriptions of the assumptions and calculations are available (Levine, 1969, 1965). Kamil and Hunter (1970a, b) applied this model to data obtained from mynas and bluejays. In essence the model assumes that a variety of hypotheses are available to a subject at the outset of each problem. The subject is seen as choosing between these "strategies". The hypotheses are mutually exclusive and it is assumed that once selected, a particular hypothesis "determines the behavior during the three trials of that problem in a precisely specifiable way." (Levine, 1965).

It is clear from the above description that several notions of process are inherent in the Levine formulation. First, the idea of "strategies" suggests an abstraction of LS somewhat different from a more traditional S-R approach to choice behavior (Reese, 1964). The additional assumptions that follow definitely describe a cognitive behavior pattern. Unfortunately, the fact that Levine's analysis describes LS behavior in a meaningful

fashion does not prove that the true process by which monkeys and/or birds solve LS has been found.

Therefore, additional evidence must be sought to either corroborate or weaken the notion of "hypothesis behavior". Experimental results obtained by Schusterman (1964) and Warren (1966), and mentioned earlier in connection with Hodos, provide some clarity. Warren's discovery that rhesus monkeys show great positive transfer from reversal tasks to LS is circumstantial proof of hypothesis behavior. In this case a "win-stay-lose-shift" hypothesis applied to the object dimension (WLS-O) is maximally efficient in both cases.

However, another purpose of this experiment was to examine an additional dimension of LS behavior, especially as it bears on the notion of hypothesis behavior. To be explicit, both the two-dimensional (2D) and the three-dimensional (3D) apparatuses were designed to record latency of the choice response.

In general, the suggestion to collect extensive latency data was prompted by the previously noted implication of cognitive behavior in the hypothesis analysis. Human learning has employed latency widely as a measure of reaction time, decision time, etc. If bluejays (or any species for that matter) choose between and employ strategies of responding while solving LS problems, one might expect this behavior to be meaningfully reflected



in latency measures. For example, Levine (1969) cites certain theoretical views of human hypothesis behavior which predict greater latencies after errors. Specifically, it is frequently assumed that human subjects do not retain an hypothesis after an error. Rather, they abandon the obviously incorrect hypothesis (and perhaps others similar to it) and scan the remaining hypothesis for a new one (Trabasso and Bower, 1968). Such a process would produce greater latencies on trials following errors.

One final variable has been isolated in this experiment, a "nest" variable. During the course of conducting LS research with bluejays, it has been observed by myself and others that certain subjects exhibit behavioral mannerisms and patterns of responding that are very similar. On occasion, the patterns of similarity seem so orderly that one must suspect the operation of an unidentified variable. In response to this suspicion it was decided to employ bluejays from two broods in this study, balancing the nestmates across experimental groups. The discovery that brood or "nest" was a significant variable would be a valuable piece of knowledge. In addition to identifying a source of variability in studies using few subjects, such a finding would implicate an intra-species dimension over which LS behaviors can vary.

## METHOD

Subjects. The subjects were eight bluejays (Cyanocitta cristata) captured locally when approximately fourteen days old, and hand-raised in the laboratory. After rearing, the subjects were maintained on a free-feeding schedule of food and water for 4½ months prior to the experiment. Four subjects were from Nest 1 and the other four were from Nest 2. Nest 1 was found in a spruce tree located in the front yard of an occupied home. The tree was five yards from the house and fifteen yards from a road. The general vicinity surrounding this nest contained several homes and frequently traveled roads. Nest 2 was taken from a large pine tree located on the edge of a wooded area about 50 yards from a home. The area around this nest was undeveloped and contained few homes. For the experiment, the subjects were grouped into two experimental groups of four each, balanced across nests. One subject from Nest 1 died prior to the last phase of the experiment. His group completed the experiment with three subjects.

Apparatus. The 3-D apparatus (referring to the stimuli) was a modified version of the WGTA similar to that employed by Kamil and Hunter (1970). The bird chamber was made of masonite, 26.7x33x33 cm. high. A small wooden enclosure was attached to the animal chamber on the end nearest the perch. The interior floor of this

enclosure contained two shallow foodwells, 8 cm. apart. At the bottom of each foodwell a light-sensitive photocell was located, protected by glass. The subject's access to the foodwell area was through a partitioned rectangular window, and an aluminum guillotine door separated the two chambers. On the side of the door nearest the foodwells a pecking key was mounted and illuminated by a .1 W bulb. A circular hole was cut in the door so that the subject was presented with a round stimulus key when the door was closed. The interior of the foodwell area was illuminated by two 10 W bulbs, and all interior portions of the apparatus were painted with non-toxic, grey paint.

During experimental sessions, the animal chamber was inserted into an acoustically-tiled cubicle inside which masking white noise was generated. Attached to this cubicle was a solenoid that operated to lift the guillotine door.

The 2D apparatus was a custom-built Lehigh Valley bird chamber. The interior of the chamber was partitioned by a metal panel creating an area 30x33x37 cm. high in which the subjects were tested. A perch was mounted 13 cm. above the floor and 4 cm. from the panel. The metal panel contained three stimulus keys arranged horizontally 3 cm. apart, and 24 cm. above the floor. In addition, a foodcup was located directly below the center key and protruded 2 cm. into the subject's area. The center key was circular, 2.5 cm. in diameter, while the two side keys

were square, 4.5 cm. on a side.

A Davis universal feeder, model no. UF-100, was mounted on the roof of the bird chamber, and delivered reinforcement to the food cup via a rubber tube connecting through the top of the apparatus. In addition, a carousel projector was located outside the apparatus, projecting through a rectangular hole in the exterior and onto the two side stimulus keys.

A moderate amount of relay equipment was located in a room adjacent to the rooms where the two apparatuses were located and was used to coordinate the operation of the feeder, projector, and bird chamber during experimental sessions. Latency was recorded on a printing counter in units of approximately .1 sec. The stimuli in the 3-D situation were 100 multi-dimensional, "junk" objects (toys, wooden frames, etc.). For the other experimental group a population of 100 stimuli were photographed and presented via the projector as two-dimensional forms. These stimuli were taken from several sources including magazines, posters, photographs, etc. Reinforcement in both situations consisted of one-half of a tenebrio larva.

Procedure. The experiment was divided into four stages: habituation, shaping, learning set acquisition, and transfer. During habituation each subject was exposed to food deprivation and gradually reduced to 85% body weight. At the same time as habituation to deprivation



began, each subject was given daily sessions in the appropriate apparatus with reinforcement available in the foodwells or foodcup. The second stage began with shaping by successive approximations the behaviors involved in affecting a choice response. During this phase neutral forms, i.e., plain wooden blocks, served as stimuli for the subjects in the 3-D situation (Group 1). Once the subjects in this group had learned to retrieve food from a completely covered foodwell, the response of pecking the key mounted on the door was shaped. The subjects learned quickly to peck this key causing the guillotine door to rise and allow access to the stimulus blocks. During all stages prior to acquisition care was taken for both groups not to provide differential reinforcement based on any cues in the situation.

The birds performing in the 2-D apparatus (Group 2) were shaped in a similar fashion. Initially they were trained to peck the two side keys to obtain reinforcement. Next, they were quickly taught to peck the center key in order to turn on the side keys.

Intertrial intervals for LS acquisition by the two groups were arranged as follows. In the 3-D apparatus a 20 sec. ITI followed each choice response. At the end of this period the door-mounted key was illuminated and its connection to the solenoid was made operative. In the 2-D apparatus a 20 sec. interval also served as the

ITI. In this case an incorrect response resulted in 20 seconds of darkness after which the house light and center key were activated. A correct response resulted in reinforcement delivery and three seconds during which the feeder light was illuminated. Darkness then followed for 17 seconds resulting in a 20 sec. ITI.

Learning set acquisition followed immediately after shaping. Throughout acquisition the previously specified latencies were measured in the following manner: (1) the subject's key peck to the center key started the latency timer simultaneous with the appearance of the choice stimuli, (2) the timer stopped when a choice response occurred. In the 3-D apparatus, the sensitivity of the photocell circuits was adjusted so that displacement of either object far enough to uncover a foodwell tripped a relay stopping the clock.

The initial acquisition problems for both groups were run to a criterion of 20/25 correct or ten consecutive correct responses (Kamil and Hunter, 1970). The 3-D group had five such problems after which problem length was systematically decreased in order to facilitate intra-problem learning (Harlow, 1959, and Hunter and Kamil, 1971). For this group problem length was decreased as follows: problems 6 to 15 - 25 trials each, problems 16 to 50 - 15 trials each, problems 51 to 120 - 10 trials each, and problems 121 to 300 - 6 trials each. The 2-D

group received 15 of the initial criterion problems followed by: problems 16 to 30 - 25 trials each, problems 31 to 100 - 15 trials each, and problems 101 to 350 - 10 trials each.

During the last phase of the experiment the two groups switched apparatuses and 100 transfer problems were run (prior to transfer one of the subjects - S71 - in Group 1 died). After a few shaping sessions identical to those described earlier, each group received five 25 trial criterion problems in their "new" box. The subsequent 95 problems were six trials in length for Group 1 and ten trials in length for Group 2.

The construction of the lists of object pairings and the sequences of reward and object placement are outlined in Kamil and Hunter (1970). For both groups, the hundreds of stimulus-pairs required were obtained by a random repairing procedure. As in earlier experiments, all the possible sequences of position that reward could take during the first three trials were employed equally throughout acquisition and transfer. With this restriction, position of the correct stimulus varied randomly in all problems for all subjects.

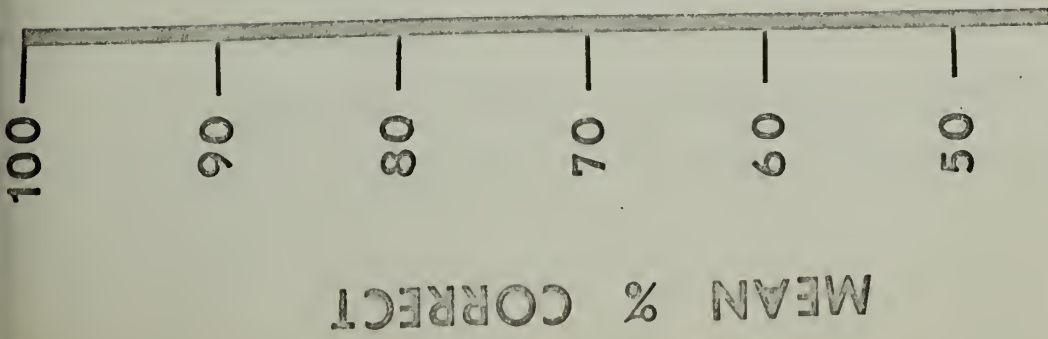


## RESULTS AND DISCUSSION

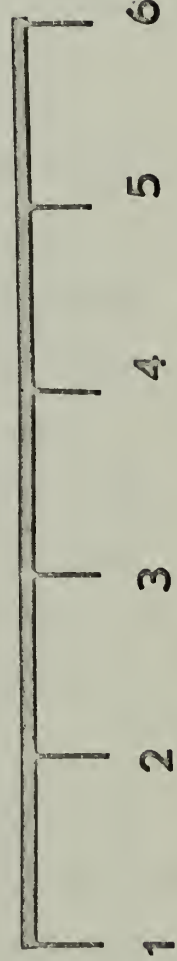
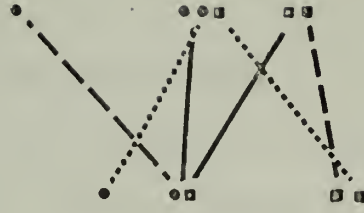
The results and discussion portion of the experiment is presented in four sections. The first section presents and discusses data pertaining to percentage correct responding. The second section does the same for latency of response, while the third part deals with the analyses of hypothesis behavior. The final section is a general discussion.

## PERCENTAGE CORRECT DATA

Figure 1 shows the average percentage correct for Trials 1-6 for Group 1 (3-D apparatus). Acquisition is divided into six 50-problem blocks. Printed below each block is the total number of trials of acquisition up to and including that block. The results pictured in Figure 1 clearly indicate the formation of a LS with 72% correct responding for Trial 2 over the last block of acquisition. The separation between the curves suggests a meaningful pattern of intraproblem learning throughout acquisition. Consistent with earlier results (Hunter and Kamil, 1971), the values for Trials 4-6 appear to reach asymptote in the region of 90% correct. The final values for Trial 2 (72%) and Trial 3 (82.5%) are also comparable to previous findings for bluejays and mynas. The curve for Trial 1, which fluctuates closely around 50% correct, suggests that reward-correlated cues were absent prior to the second trial of each problem.



TRANS.



PROBLEM BLOCKS

Cumulative Trials

1000

1500

1980

2280

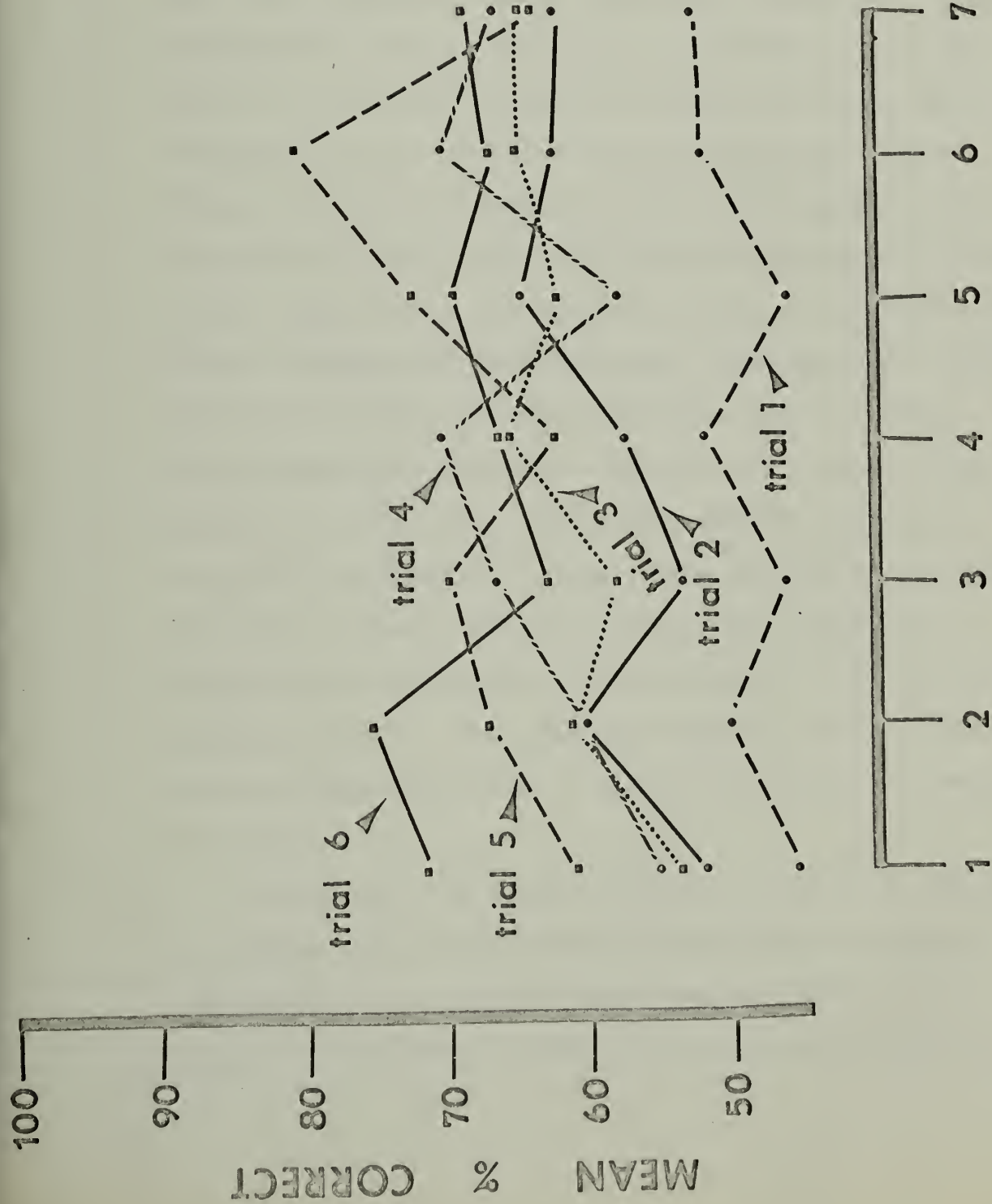
2580

2880

Figure 2 contains the acquisition and transfer data for Group 2. On this graph acquisition is divided into seven 50-problem blocks and transfer is again presented in two 50-problem blocks. Group 2 curves for acquisition, in contrast to those for Group 1, suggest that LS behavior was erratic for these birds. The upward trend in percentage correct responding for Trials 2-4 suggests the acquisition of some LS behavior. However, certain aspects of the data indicate that acquisition in the 2-D apparatus was quite different from that in the 3-D apparatus. First, the levels of correct responding for Trials 2-6 throughout acquisition are lower than those for Group 1. For example, Trial 2 and Trial 3 each asymptote in the range of 62-65% correct. Although the data points are somewhat variable for Trials 4-6, the curves for these trials do not consistently exceed a level of 70% correct. Again, the curve for Trial 1 fluctuates around 50% throughout acquisition.

Clearly, the curves for several of the trials in Figure 2 trace an erratic pattern over acquisition. For example, Trial 6 levels of correct responding are highest for the first two blocks of acquisition. Percentages correct for Trials 4 and 5 are also quite variable prior to transfer. Furthermore, there is less evidence of separation between the acquisition curves in Figure 2. These findings indicate that intraproblem learning was not

TRANS.



# PROBLEM BLOCKS

Cumulative Trials 2000 2750 3250 3750 4250 4750 5250



only less complete for Group 2, it was also less consistent from one problem block to the next.

The principal differences in acquisition by Group 1 and Group 2 can be summarized as follows. First, Group 1 acquired "superior" LS behavior as indicated by a comparison of percentage correct values for Trials 2-6. Second, acquisition data for Group 1 is more orderly than for Group 2 and reflects Group 1's consistent intraproblem learning during each block of the experiment. Third, Group 1 acquired LS behavior faster than Group 2. The cumulative trials presented along the abscissas of Figures 1 and 2 show that the subjects in Group 1 received fewer trials through each problem block. Furthermore, a tally of the first five criterion problems for each group showed that this difference was present from the start of acquisition. On the average each subject in Group 1 required 230 trials to complete the initial five problems, while the average value for Group 2 was 450 trials. There was no overlap among the subjects in the two groups on this measure. This finding suggests strongly that each individual problem in the 2-D situation was harder to solve.

The results of transfer provide additional information for comparing LS performance obtained under these two experimental procedures. The transfer data seen in Figure 1 (transfer of Group 1 to 2-D stimuli after training

with 3-D) reveal a striking drop in percentage correct responding for all trials across both problem blocks. Contrasting Group 1's transfer data to the acquisition data in Figure 2 allows two interesting comparisons. First, the levels of correct responding for Group 1 during transfer are clearly below Group 2's initial performance during acquisition in the 2-D apparatus. Second, Figure 1 reveals that Group 1's transfer data is erratic and suggests little or no intraproblem learning. This disorderly picture obtained when transferring to 2-D stimuli parallels the variable data described earlier for acquisition in a 2-D situation.

Examination of the transfer data from Figure 2 (transfer of Group 2 to 3-D stimuli after training with 2-D) provides still further information. In this case the pattern of data points for the separate trials suggests clear evidence for inter- and intra-problem learning. At the same time, however, comparison with Group 1's acquisition data again shows a negative effect of prior training in the alternative LS procedure. It is interesting to note that Group 2's transfer data provide further evidence of the orderliness of LS behavior obtained in the 3-D apparatus.

The results presented so far suggest the following generalizations about LS performance obtained from bluejays under two and three dimensional procedures. First,

consistently higher levels of correct responding are attained in the 3-D apparatus. Second, this same situation results in more orderly data clearly reflecting intra- and inter-problem learning. Finally, these same generalizations hold true in transfer with the additional observation that prior experience in either of the LS situations produces negative transfer when the subjects are tested in the other LS situation.

Group 2's performance during acquisition allows certain comparisons between bluejays and pigeons (Zeigler, 1961) tested in 2-D, LS situations. First, the pigeon's performance level of 60% correct responding over Trials 2-8 (for the two best birds in the study) is below that obtained from bluejays in this experiment. Averaging over all the subjects in Group 2 for the last block of acquisition produces a figure of 65% correct responding for Trials 2-6. The same figure calculated for the two birds in Group 2 who generated the highest percentages of correct responding is 73%. It is important to point out that this difference in overall percentage correct does not exist only when comparing Group 2's last block of acquisition with the pigeon data. Rather, it existed as early as the second block of acquisition when each bird had received only 2750 LS trials (compared to Zeigler's pigeons who apparently received more than 3000 trials).

A further examination of performance during acquisition



by each subject in Group 2 provided an important observation. One subject's performance (S70) was consistently higher and more orderly than the other three. On the last problem block of acquisition S70's percentages correct were: Trial 2 - 70%, Trial 3 - 78%, Trial 4 - 86%, Trial 5 - 86%, and Trial 6 - 88%. S70 reached this general level of performance as early as the second block of acquisition. It is important to note that not only was this bird's performance higher in terms of correct responding, it was always very orderly, similar to acquisition curves for Group 1. Incidentally, S70's performance during transfer was not distinguishable in any way from the other subjects in Group 2.

At the very least, S70's performance suggests that bluejays are capable of LS formation in the 2-D apparatus that is comparable to that obtained in the 3-D apparatus. However, the fact that three out of four subjects in Group 2 were not able to solve the task with greater success indicates there is something in the 2-D situation that generally hinders LS acquisition.

Among the factors that could have caused Group 2's lower performance, the 2-D stimuli are especially suspect. Not only is actual depth of field missing with these stimuli, variance in the physical size, shape, texture, and response requirements are also missing. Only to the extent that the bird attends carefully to the cues contained

in the depiction of the stimulus can he reinstate these attributes. In support of this notion, a difference was informally observed between the responding of S70 and the other subjects in Group 2. It appeared to the experimenter that S70 usually directed his response to a particular feature of the stimulus depiction. In contrast, each of the remaining three subjects directed its responding to a certain segment of the stimulus key regardless of the depiction on the key, e.g., the lower left corner. It would seem that a subject who is responding to features in the stimulus depiction is employing richer and more varied cues during LS acquisition.

Comparison of two and three dimensional stimuli raises another possibility recently stated by Williams (1971). Williams found that pigeons could acquire a delayed color alternation task only after the subjects were required to emit either 15 or 30 responses to the correct stimulus. He suggests that this FR effect may be interpreted in terms of the opportunity to inhibit error-producing response tendencies. The findings in the current study can easily be interpreted in favor of William's hypothesis. Certainly the discrete response of a single key peck in the 2-D apparatus provides little opportunity to change choice once a response is started. On the other hand, the displacement of a 3-D object is potentially a

less discrete response that would allow more opportunity to switch objects once a response is initiated. William's hypothesis is weakened somewhat by the observation that often the 3-D objects were forcefully displaced with a single peck. Despite this fact, the general notion of the FR effect certainly merits attention in future LS designs.

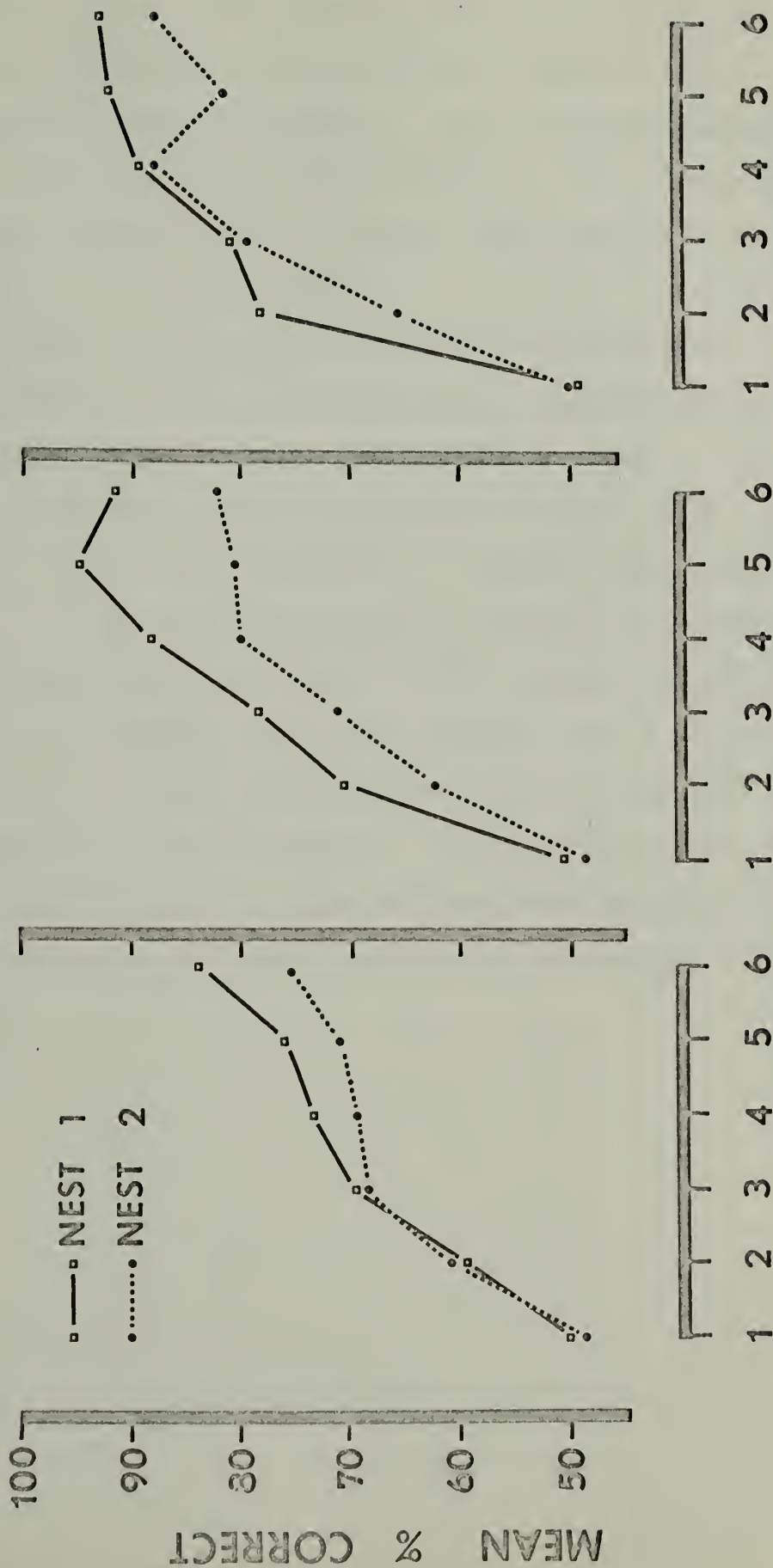
Other factors that might have contributed to Group 2's generally lower performance are lack of response-reward contiguity and perhaps automation in general. Both of these factors were mentioned in the introduction when comparing Zeigler's methodology to that of Hunter and Kamil (1971). Little more need be said about these variables except to point out the possibility of future research to explore their effects on performance. For example, it would be easy to modify a 3-D apparatus so that reinforcement is delivered via a single foodcup below the guillotine door, thus removing response-reward contiguity. Similarly, one could present 2-D stimuli in a manually-operated apparatus with or without response-reward contiguity. Finally, the 2-D apparatus could be modified so that reward appears behind the key, thereby instilling contiguity.

Figure 3 divides acquisition for Group 1 into thirds and contains average percentage correct responding for each nest. Percentage correct is on the ordinate of each graph while the abscissa contains Trials 1-6. The upward

PR. 1-100

PR. 101-200

PR. 201-300



TRIALS

trends in each graph indicate orderly intra-problem learning in most cases. It is striking, however, that throughout acquisition Nest 1 obtained higher percentages of correct responding than did Nest 2. The single exception to this trend occurs for Trial 2 over the first 100 problems of the experiment.

Figure 4 contains analogous data for Group 2. In this case the first two blocks each represent 100 problems, while the third contains 150 problems. Again, it is clear that percentage correct responding for Nest 1 is consistently higher than for Nest 2. However, any strong statement of a "brood" effect based on Figure 4 is clouded by the individual performance of S70, alluded to earlier.

The results pictured in Figures 3 and 4 certainly serve as a first indication that brood was an active variable in this experiment. Since evidence from each of the next two sections also corroborates this notion, discussion of the "nest variable" is postponed until later.

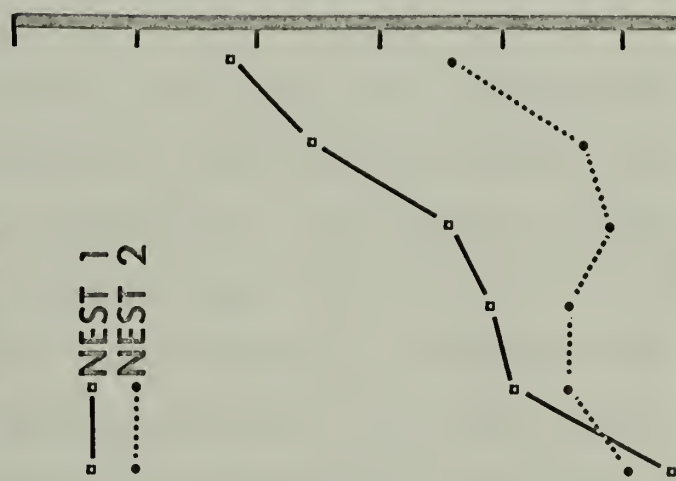


PR. 1-100

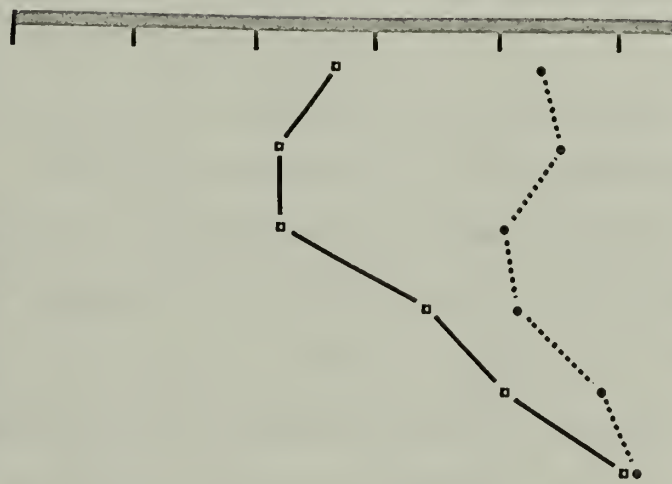
MEAN % CORRECT

100  
90  
80  
70  
60  
50

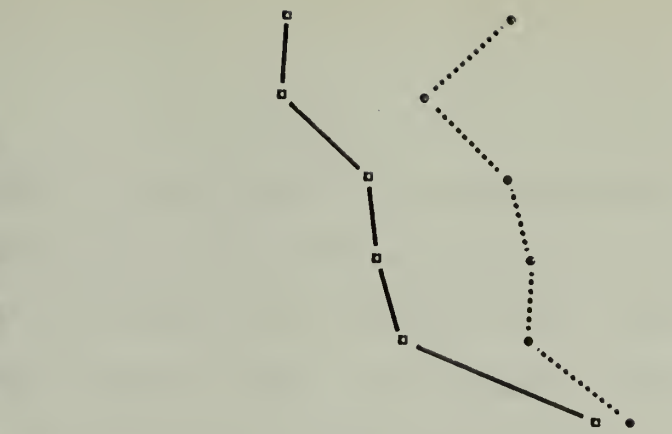
—□— NEST 1  
.....•..... NEST 2



PR. 101-200



PR. 201-350



TRIALS

## LATENCY DATA

The results obtained from analyses of Trial 2 and Trial 3 latencies can be found in Appendices 1 and 2. Each analysis of variance was a seven factor, mixed-variable design (Myers, 1966). Two factors, apparatus and nest, were between-subject variables while the remaining factors were all within-subject.

Appendix 1 presents the ANOVA for the first half of acquisition. During this period of the experiment, the average latency of response was greater for Nest 1 than for Nest 2 (E factor;  $F = 15.79$ ,  $df = 1/4$ ,  $p < .025$ ). There was only one other F-ratio in Appendix 1 that approached statistical significance; the average latency was greater for Group 1 than for Group 2 ( $F = 5.20$ ,  $df = 1/4$ ,  $p < .10$ ).

The ANOVA for the second half of acquisition, presented in Appendix 2, contains no F-ratios that reach the .05 level of significance. However, the average latency for Nest 1 is again longer than Nest 2 ( $F = 5.38$ ,  $df = 1/4$ ,  $p < .10$ ). Furthermore, the average latency for Group 1 is again greater than for Group 2, although the F is not statistically significant ( $F = 4.28$ ,  $df = 1/4$ ,  $p < .25$ ).

It should be noted that each of these F-ratios is based on very few degrees of freedom; one in the numerator and four in the denominator. Clearly, these are not the



best circumstances for detecting statistical significance. Therefore, the size of the F-ratios for the Nest factor, especially the significant F reported in Appendix 1, strongly supports the notion that Brood was an active variable throughout this study. It is also suggestive that Nest 1, which ranked higher for percentage correct responding (Figure 3), recorded longer latencies throughout acquisition. The indication in these two analyses that the average latency of response may have been greater in the 3-D apparatus is worth mentioning here, despite the lack of statistical significance. Perhaps there is a relationship between how successfully a subject acquired learning set and his latency of choice response. Such a relationship would be supported by longer latencies from Group 1, who generated much higher percentages of correct responding during acquisition. Further support for the relationship is evident by Nest 1's longer latencies mentioned above. Although the paucity of clear statistical significance demands caution in our reasoning, at the very least these findings indicate the useful role that latency analyses may play in future learning set studies.

One of the several goals of this research was to examine certain theoretical notions of process contained in Levine's (1959) model of hypothesis behavior. In particular, attention was focused on Levine's assumption that a subject employs a single hypothesis for the first

three trials of any given problem. This assumption is at odds with more recent models of hypothesis behavior for humans (Levine, 1970) which predict hypothesis switching after errors. Assuming that it takes more time to switch a hypothesis than to retain it, these later models also predict longer latencies following errors.

The results of the current latency analyses are relevant to this inquiry, especially the conspicuous lack of significant factors in both ANOVA's. For example, latency of response is no longer following incorrect responses as hypothesis switching theories would predict. In addition, these results indicate that latency does not systematically vary with; (1) shift or nonshift in position of the rewarded object on the previous trial, (2) reward or nonreward on the current latency trial, and (3) Trial 2 or Trial 3 of a problem. Remembering that statistical nonsignificance is unsound support, it can at least be stated that the above results are consistent with Levine's (1959) model of hypothesis behavior.

The principal results reported in this latency section can be summarized as follows. First, the Brood variable emerged as the largest statistical factor in both halves of the experiment with Nest 1 generating longer latencies. Second, there was some suggestion that response latency was greater in Group 1 (3-D), however this factor was not statistically significant. Third, the results of both

ANOVA's failed to support the notion that subjects switched hypotheses during the first three trials of a problem. This finding is consistent with Levine's (1959) model of hypothesis behavior. Finally, both analyses in this section testify to the obvious problem in small n research. Unfortunately, this problem will not be resolved easily in learning set research where each subject "demands" so much of the experimenter's time.

## HYPOTHESIS ANALYSIS

Table 3 presents seven sets of hypothesis estimates calculated for the acquisition and transfer data obtained from Group 1. Levine's model of hypothesis behavior was employed to obtain these estimates. The far left column designates the particular subjects and block of problems involved in each row of estimates. The far right column contains the percentage variance explained (PVE) value calculated for each set of hypotheses. This statistic is in the form of a squared correlation coefficient and attempts to monitor the internal consistency of Levine's hypothesis calculating procedure.

Looking at Table 3, one can see that all PVE values except one are greater than .6. This is equivalent to saying that in six of seven cases the observed hypothesis values account for at least 60% of the variance in the data. Rows one and four contain estimates for the first and second half of acquisition for the entire group. The largest changes in hypothesis estimates occurred for: (1) Position Preference - decrease from .148 to .008, (2) Stimulus Preference - decrease from .182 to .094, (3) WSLs-object - increase from .319 to .379, and (4) PVE-increase from .654 to .773. Each of the first three findings (and perhaps the fourth as well) is in accord with the observed formation of LS behavior.

Rows two and five in Table 3 present estimates for the

TABLE 1

HYPOTHESIS PROBABILITIES  
AND P.V.E. VALUES FOR GROUP 1

GROUP (Problem Block)	H Y P O T H E S E S								
	Position Prefer- ence	Position Alter- nation	Win-Stay Lose-Shift (Position)	Stimulus Prefer- ence	Stimulus Alter- nation	Third- Trial Learning	Win-Stay Lose-Shift (object)	Random Respond- ing	P.V.E.
Everyone (1-150)	.148	.027	.084	.182	-.012	.174	.319	.044	.654
Nest 1 (1-150)	.010	-.010	.106	.231	.014	.150	.318	.062	.798
Nest 2 (1-150)	.270	.062	.057	.133	.012	.201	.323	.023	.319
Everyone (151-300)	.008	.018	.074	.094	.065	.181	.379	.047	.773
Nest 1 (151-300)	-.004	.046	.119	.098	.097	.198	.445	.016	.718
Nest 2 (151-300)	.029	-.011	.031	.089	.031	.165	.306	.079	.677
Everyone (Transfer)	.363	.037	.095	.236	.037	.056	-.118	.089	.625



first and second half of acquisition by Nest 1, while rows three and six are for Nest 2. For Nest 1 large changes occurred in: (1) WSLs-object - increase from .318 to .445, (2) Random responding - decrease from .062 to -.16, and (3) Stimulus Preference - decrease from .182 to .098. The interpretation of Nest 2's estimates over the two blocks of acquisition is more difficult due to the low PVE in row three. In spite of this handicap it seems fair to say that Nest 2 responded less to cues of position as the experiment progressed. The huge decrease in position preference supports this fact despite the generally low validity of the estimates in row three.

Perhaps the most consistent comparison between these two nests is that for PVE. In both blocks of the experiment the PVE for Nest 1 is greater than that for Nest 2. Other differences can be seen by examination of rows five and six in Table 3. Comparison of these estimates shows that Nest 1 employed more WSLs-position and WSLs-object and at the same time had less random responding. With the exception of the WSLs-position comparison, these latter findings coincide nicely with Nest 1's superiority in percentage correct.

The last row in Table 3 contains hypothesis estimates obtained from Group 1's transfer data (transfer was not analyzed by nest because only one bird from Nest 1 was run during this period). Clearly, Position Preference

and Stimulus Preference were the dominant hypotheses during transfer. It is also obvious that WSLs-object, which had previously been the principal strategy, dropped from use. These estimates document rather clearly a change in behavior precipitated by transfer to the 2-D apparatus. No longer do the birds employ a hypothesis which requires the subject to retain specific information about preceding outcomes. On the contrary, 60% of their responding is on the basis of simple preferences for either an object or a position.

The principal results in Table 3 can be stated in a few sentences. First, high PVE's were obtained in all but one case, indicating the overall applicability of Levine's model to these data. Second, hypothesis estimates for Group 1 as a whole described meaningfully the acquisition of LS behavior. Third, the suggestion of a nest variable was present in the estimates. Finally, the estimates obtained for transfer provided a meaningful picture of altered hypothesis behavior under conditions employing 2-D stimuli. On the basis of these results, the hypothesis model is certainly a robust descriptive tool.

The picture is somewhat altered as we turn our attention to Table 4. This table presents nine sets of hypothesis estimates calculated for the acquisition and transfer data obtained from Group 2. Table 4 shows clearly that the PVE's for Group 2's estimates are not so

high as those for Group 1. In this case only two of nine PVE values exceed .6. Although this finding is unfortunate in the sense that it precludes very much comparison of the hypothesis estimates, the occurrence of very low PVE's is interpreted as favorable for Levine's model. As mentioned earlier, Group 2 produced a low level of LS performance against the background of generally disorderly data. In view of these facts, Levine's model would have been suspect had it resulted in an orderly description of consistent behavior.

However, very general observations about the hypothesis estimates obtained from these data are still warranted. First, during acquisition Nest 1 again achieved higher PVE's than Nest 2. This fact agrees with earlier findings for Group 1 and implies that Levine's model is more applicable to Nest 1's LS behavior. Such a conclusion is not without support, especially Nest 1's higher percentage correct responding in all cases. On the basis of several pieces of evidence, it appears that Nest 1 acquired "better" LS, faster than Nest 2.

Another general observation based on the estimates in Table 4 is worth mentioning. Although a strong statement is impossible due to the PVE's, it appears that Nest 1 attended more to the stimulus dimension of the experimental situation. On the other hand, Nest 2 attended more to the position dimension. The only set of estimates for

TABLE 2

HYPOTHESIS PROBABILITIES  
AND P.V.E. VALUES FOR GROUP 2

Group (Problem Block)	H Y P O T H E S E S								
	Position Preference	Position Alterna- tion	Win-Stay (Position)	Stimulus Preference	Stimulus Alterna- tion	Third- Trial Learning	Win-Stay Loss-Shift (Object)	Random Respond- ing	P.V.E.
Everyone (1-176)	.195	.042	.210	.151	.013	.138	.046	.075	.070
Nest 1 (1-176)	.158	.027	.197	.181	.016	.144	.105	.059	.268
Nest 2 (1-176)	.232	.056	.217	.127	.016	.135	-.004	.089	-.381
Everyone (177-350)	.088	.047	.237	.147	.046	.182	.143	.049	.472
Nest 1 (177-350)	.084	.043	.210	.219	.022	.174	.263	.027	.666
Nest 2 (177-350)	.104	.054	.261	.088	.063	.192	-.001	.070	.137
Everyone (Transfer)	.180	.113	.108	.356	-.048	.146	.026	.038	.554
Nest 1 (Transfer)	.188	.125	.123	.375	.028	.198	-.024	.039	-.104
Nest 2 (Transfer)	.140	.101	.062	.331	.033	.083	.067	.039	.725
									36

acquisition with a reasonable PVE are for Nest 1, problems 177-350. These figures show that nearly 50% of the responding was due to Stimulus Preference and WSLS-object. Other hypotheses in this row receiving high estimates included WSLS-position and Third Trial Learning. However, it is likely that S70's remarkable performance referred to earlier is responsible for the size of the WSLS-object strategy. Indeed, it is quite probably that S70, who apparently solved the LS paradigm despite 2-D stimuli, is also the major reason for Nest 1's higher PVE values in Table 4.

The results of transfer (rows 7-9 in Table 4) are also obscured by some low PVE values. However, this time it was Nest 1 who obtained the low value. In general, the estimates from transfer indicate a large shift to Stimulus Preference. Contrary to possible expectations, WSLS-object does not emerge over the 100 problems of transfer as a major strategy.

Before going on to a final discussion, the general results in this section can be summarized as follows. First, the orderliness of LS acquisition in the 3-D apparatus was supported by the high PVE's in Table 3. At the same time, the low PVE's reported in Table 4 parallel the earlier observation that during acquisition Group 2's LS behavior was always less orderly than Group 1's. Collectively, these findings give additional support



to the Levine model, and especially to its power as a descriptive tool. Finally, this section of results has also "discovered" the ubiquitous nest effect, not only in the pattern of PVE's, but to a lesser extent in the hypothesis estimates themselves.

## FINAL DISCUSSION

A major purpose of this experiment was to examine critically the application of Levine's model of hypothesis behavior to LS data obtained from bluejays. Several results relevant to this inquiry were reported in earlier sections and will be reiterated at this time. Although Levine's basic assumptions concerning hypothesis behavior do not contain any statement concerning the latency of response, certain implications are present (Levine, 1965, p. 101). In particular, Levine assumes for the sake of calculations that once a hypothesis is chosen at the outset of a problem, behavior is determined in accordance with that hypothesis for at least three trials. Under these circumstances there is little reason to expect latency to vary with reward or nonreward on a prior trial. As reported earlier, the patterns of response latency observed in this study do not contradict this notion.

The results from the hypothesis analysis in the last section also support Levine's model. First, the estimates that were acquired from Group 1 provided a meaningful picture of LS behavior. Not only did these estimates differentiate between the two blocks of acquisition and clarify behavior changes in transfer, they also indicated differences between the two nests that were consistent with earlier observations. Other studies, Kamil and Hunter (1970) and Hunter and Kamil (1971) have also demonstrated the fine descriptive ability that this model possesses.

However, the current hypothesis estimates through their pattern of PVE's have provided new evidence that Levine's organization of behavior in terms of hypotheses is correct. In this case, the principal findings were two: (1) PVE's for Group 1's acquisition were substantially higher than those for Group 2's acquisition, and (2) Nest 1's PVE's were generally greater than Nest 2's during acquisition. Both of these findings indicate that as successful LS behavior developed in particular subjects, the applicability of Levine's model was also greater. Lower PVE's from groups demonstrating "inferior" performance suggests that they employed hypotheses differently than the model assumes, or that their behavior was not properly viewed as hypothesis behavior. In either case, Levine's model detected deviations from its assumptions in precisely those groups whose LS behavior was marginal and/or disorderly during acquisition.

It is worth noting that an additional attempt was made to test Levine's model combining latency data and hypothesis estimates. The goal was to obtain estimates for the latency associated with each strategy. Unfortunately, the calculations, which were based on several unproven assumptions, lacked internal consistency. Therefore, it appears based on the previous discussion, that Levine's model is largely supported by the results of this experiment. This is particularly true since earlier

criticism of Levine's assumption that a single hypothesis is retained for the first three trials of a problem (Hunter and Kamil, 1971) was not supported by analyses of response latency in this study.

The final discussion concerns the pervasive effect of nest or brood. In each of the previous sections strong evidence was obtained in connection with this factor. Summarizing the principal results shows that on the average Nest 1 obtained: (1) higher percentages of correct responding, (2) longer latencies, (3) greater differences in latency as a function of prior reward or nonreward, and (4) higher PVE's. It would be interesting to speculate for a moment about the possible reasons that this variable was so evident. First, however, it should be noted that an attempt was made to collect the nests when the respective nestlings were at similar stages in ontogeny. Development of feather tracts and especially the growth of primary flight feathers were employed to compare nestling development. Once in the laboratory, all young birds received the same diet, handling, and overall maintenance.

There is the possibility that these differences are due to a difference in genetic make-up between nests. The fact that each nest draws its genetic characteristics from a different set of parents provides a strong basis for predicting similarities within nests. A far less convincing argument on the side of nest differences in

genetic make-up suggests that the two nests are representative of two genetically different "groups" of bluejays. At this time, there is no evidence that such a situation exists in the Northern Bluejay (Cyanocitta cristata).

However, in addition to different parents, the nests were obtained from somewhat different surroundings. As stated earlier, laboratory records show that Nest 2 was located on the edge of a wooded area about 50 yards from the nearest human dwelling or road. It was also noted that the general vicinity around this nest was relatively undeveloped and did not contain a high density of houses. On the other hand, Nest 1 was taken from a solitary spruce tree located in the front yard of an occupied house. This location was less than 15 yards from a moderately traveled road and in an area with many more houses.

Perhaps one or more of these differences in habitat may have allowed for different early learning experiences between nests. For example, one might theorize that Nest 1 was provided with more opportunity to habituate to human presence. However, if this actually occurred, it was not apparent in the ease with which each bird was handled as an adult.

It is clear that no reliable statement can be reached concerning the cause of the nest effect. However, the



extent to which this variable was active throughout the experiment should be sufficient cause to note its contribution in future studies.

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SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE
1 MEAN	614.9086	1	614.9086
2 A	25.1429	1	25.1429
3 B	1.5687	1	1.5687
4 C	7.8755	1	7.8755
5 D	0.2655	1	0.2655
6 E	76.4003	1	76.4003
7 F	1.0749	1	1.0749
8 AB	0.1561	1	0.1561
9 AC	1.1877	1	1.1877
10 BC	0.2424	1	0.2424
11 AD	0.0549	1	0.0549
12 BD	0.0010	1	0.0010
13 CD	1.7228	1	1.7228
14 AB	14.7628	1	14.7628
15 BE	0.5447	1	0.5447
16 CE	5.8013	1	5.8013
17 DE	0.0963	1	0.0963
18 AF	0.4039	1	0.4039
19 BF	0.1333	1	0.1333
20 CF	2.6941	1	2.6941
21 DF	0.1718	1	0.1718
22 EF	0.9028	1	0.9028
23 S(AE)	19.3527	4	4.8382
24 ABC	0.0856	1	0.0856
25 ABD	0.0250	1	0.0250
26 ACD	0.5900	1	0.5900
27 BCD	0.0591	1	0.0591
28 ABE	0.8861	1	0.8861
29 ACE	0.2583	1	0.2583
30 BCE	1.5378	1	1.5378
31 ADE	0.0006	1	0.0006
32 BDE	0.0689	1	0.0689
33 CDE	0.6714	1	0.6714
34 ABF	0.0309	1	0.0309
35 ACF	0.0328	1	0.0328
36 BCF	0.2072	1	0.2072
37 ADF	1.3757	1	1.3757
38 BDF	0.3210	1	0.3210
39 CDF	0.7155	1	0.7155
40 AEF	0.0662	1	0.0662
41 BEF	0.2056	1	0.2056
42 CEF	0.3730	1	0.3730
43 DEF	0.3905	1	0.3905
44 BS(AE)	1.9368	4	0.4842
45 CS(AE)	1.5463	4	0.3866
46 DS(AE)	0.1962	4	0.0491
47 ES(AE)	0.4108	4	0.1027
48 ABCD	0.1372	1	0.1372



49	ABCE	0.0000	1	0.0000
50	ABDE	0.8144	1	0.8144
51	ACDE	0.0328	1	0.0328
52	BCDE	0.0022	1	0.0022
53	ABCF	0.0002	1	0.0002
54	ABDF	0.2008	1	0.2008
55	ACDF	0.7066	1	0.7066
56	BCDF	0.9713	1	0.9713
57	ABEF	0.2186	1	0.2186
58	ACEF	0.0591	1	0.0591
59	BCEF	0.0375	1	0.0375
60	ADEF	0.0785	1	0.0785
61	BDEF	0.0068	1	0.0068
62	CDEF	0.0389	1	0.0389
63	BCS(AE)	1.7236	4	0.4309
64	BDS(AE)	0.8047	4	0.2012
65	CDS(AE)	0.3852	4	0.0963
66	BFS(AE)	0.2612	4	0.0653
67	CFS(AE)	0.1927	4	0.0482
68	DFS(AE)	2.1489	4	0.5372
69	ABCDE	0.0424	1	0.0424
70	ABCDF	0.0396	1	0.0396
71	ABCEF	0.0898	1	0.0898
72	ABDEF	0.1838	1	0.1838
73	ACDEF	1.5864	1	1.5864
74	BCDEF	0.0866	1	0.0866
75	BCDS(AE)	0.3797	4	0.0949
76	BCFS(AE)	0.1316	4	0.0329
77	BDFS(AE)	0.7983	4	0.1996
78	CDFS(AE)	0.8078	4	0.2019
79	ABCDEF	0.7006	1	0.7006
80	BCDFS(AE)	3.6787	4	0.9197

SOURCE		SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE
1	MEAN	961.1920	1	961.1920
2	A	70.6860	1	70.6860
3	B	0.6903	1	0.6903
4	C	18.2361	1	18.2361
5	D	8.3130	1	8.3130
6	E	88.3785	1	88.3785
7	F	1.6065	1	1.6065
8	AB	0.5101	1	0.5101
9	AC	0.2945	1	0.2945
10	BC	0.0657	1	0.0657
11	AD	13.8733	1	13.8733
12	BD	0.1876	1	0.1876
13	CD	1.1705	1	1.1705
14	AE	2.3871	1	2.3871
15	BE	2.5533	1	2.5533
16	CE	10.4768	1	10.4768
17	DE	1.7438	1	1.7438
18	AE	7.1159	1	7.1159
19	BF	0.0109	1	0.0109
20	CF	2.3545	1	2.3545
21	DF	2.3871	1	2.3871
22	EF	0.1001	1	0.1001
23	S(AE)	66.0413	4	16.5101
24	ABC	0.2646	1	0.2646
25	ABD	0.0358	1	0.0358
26	ACD	0.0435	1	0.0435
27	BCD	0.6216	1	0.6216
28	ABE	0.0000	1	0.0000
29	ACE	0.1726	1	0.1726
30	BCE	0.5645	1	0.5645
31	ADE	2.6508	1	2.6508
32	BDE	0.0005	1	0.0005
33	CDE	0.2964	1	0.2964
34	ABF	0.2129	1	0.2129
35	ACF	2.3871	1	2.3871
36	BCF	0.1352	1	0.1352
37	ADF	1.0368	1	1.0368
38	BDF	3.1001	1	3.1001
39	CDF	0.1876	1	0.1876
40	AEF	0.5592	1	0.5592
41	BEF	0.1526	1	0.1526
42	CEF	0.1152	1	0.1152
43	DEF	0.8128	1	0.8128
44	BS(AE)	2.3367	4	0.5842
45	CS(AE)	2.8033	4	0.7008
46	DS(AE)	3.0152	4	0.7538
47	ES(AE)	3.3029	4	0.8257
48	ABCD	0.0200	1	0.0200

49	ABCE	2.1788	1	2.1788
50	ABDE	0.0026	1	0.0026
51	ACDE	2.0402	1	2.0402
52	BCDE	0.4802	1	0.4802
53	ABCF	1.7391	1	1.7391
54	ABDF	1.8528	1	1.8528
55	ACDF	0.1610	1	0.1610
56	BCDF	0.0132	1	0.0132
57	ABEF	0.0109	1	0.0109
58	ACEF	0.2521	1	0.2521
59	BCEF	0.5886	1	0.5886
60	ADEF	0.0091	1	0.0091
61	BDEF	0.0001	1	0.0001
62	CDEF	1.2207	1	1.2207
63	BCS(AE)	1.6084	4	0.4021
64	BDS(AE)	1.1214	4	0.2803
65	CDS(AE)	1.6191	4	0.4048
66	BFS(AE)	0.4516	4	0.1179
67	CFS(AE)	2.6703	4	0.6676
68	DFS(AE)	4.9586	4	1.2384
69	ABCDEF	2.3113	1	2.3113
70	ABCDF	0.2869	1	0.2869
71	ABCEF	0.8911	1	0.8911
72	ABDEF	0.0820	1	0.0820
73	ACDEF	0.0345	1	0.0345
74	BCDEF	0.0226	1	0.0226
75	BCDS(AE)	3.1598	4	0.7900
76	BCFS(AE)	1.2093	4	0.3023
77	BCDFS(AE)	4.1832	4	1.0458
78	CDFS(AE)	0.3496	4	0.0874
79	ABCDEF	0.7781	1	0.7781
80	BCDFS(AE)	3.2541	4	0.8135



